(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 1 223 066 A2

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
17.07.2002 Bulletin 2002/29

(51) Int Cl.7: B60K 6/04, F02D 41/14

(21) Application number: 01204265.1

(22) Date of filing: 07.11.2001

(84) Designated Contracting States:
AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU MC NL PT SE TR
Designated Extension States:
AL LT LV MK RO SI

(30) Priority: 14.11.2000 IT BO000661

(71) Applicant: NEW HOLLAND ITALIA S.p.A.
I-41100 Modena (IT)

(72) Inventor: Bordini, Giorgio,
Edificio URBIS Portal 7 APT. 6B
E-38003 Santa Cruz de Tenerife, Canarias (ES)

(74) Representative: Vandenbroucke, Alberic
New Holland Belgium NV.
Patent Department
Leon Claeysstraat, 3A
8210 Zedelgem (BE)

(54) Method of regulating and controlling an internal combustion engine

(57) A method of regulating and controlling an internal combustion engine forming part of a hybrid power unit of a self-propelled vehicle, the method employing:

a first graph showing the power transmitted by the engine as a function of the rotational speed of a drive shaft, and for different injector openings of a power-regulating injection device; and
a second graph showing the torque transmitted by the drive shaft as a function of the rotational speed of the drive shaft, and for different injector openings of the power-regulating injection device; the second graph also showing the injector opening of the power-regulating injection device.

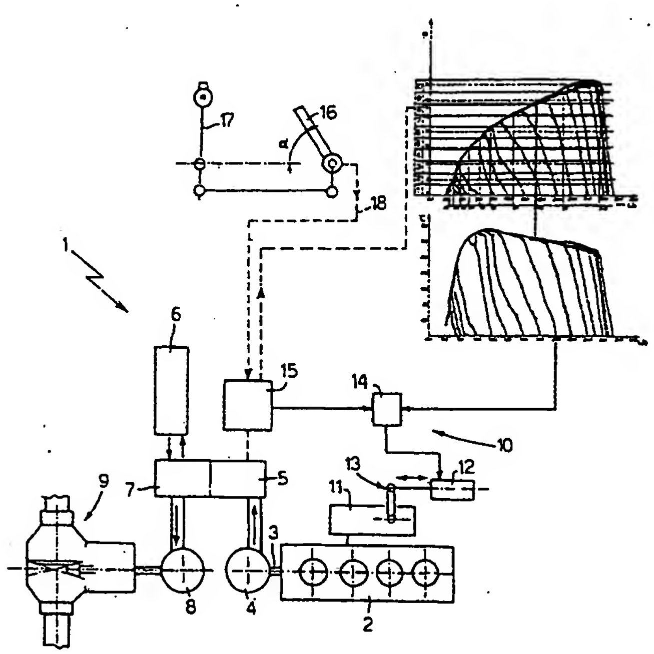

Fig.1

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Description

[0001] The present invention relates to a method of regulating and controlling an internal combustion engine forming part of a hybrid power unit of a self-propelled vehicle.

[0002] Known methods of controlling an internal combustion engine, in particular a diesel engine, are based on thousands of operational working points obtained from engine work graphs showing, for example, power and torque as a function of the rotational speed of the drive shaft. Since little ready-made data is normally available, composing reliable maps for a given engine is an enormous job in terms of data acquisition and, obviously, in terms of time and work, and seriously complicates the electronic central control unit regulating the actuator governing the diesel engine injection pump.

[0003] It is therefore an object of the present invention to provide a simplified solution - albeit approximate but nevertheless acceptable - to the problem of regulating the injection of fuel in a diesel engine to ensure low consumption, low emission of harmful gases, a low noise level, and a long working life of the engine.

[0004] The method according to the present invention can only be applied to a hybrid power unit, which, as will be seen, allows to separate the control of the optimum engine conditions from the actual traction power required.

[0005] Since the engine-wheel gear ratio is continuously variable, vehicle speed may vary independently of engine speed, which may therefore be selected to suit a given vehicle speed, which at best should provide for reducing specific fuel consumption (SFC), pollutant emissions, noise level, and engine wear, while at the same time preserving the elasticity and control response of the engine.

[0006] For a given traction power, current regulating methods fail to provide for transmitting the power of the engine under maximum-torque conditions. Since specific fuel consumption of an engine is minimum under maximum torque conditions, and since the noise level also increases alongside engine speed, the engine, for a given traction power, should be operated at minimum speed while at the same time providing the mean traction power required by the terrain. For this to be done, the operating point of the engine must be located on the maximum-torque curve, which means that the right injection pump setting has to be determined at which the engine is enabled to supply the necessary instantaneous power in the best conditions referred to above.

[0007] According to the present invention, a method therefore is provided of regulating and controlling an internal combustion engine connected to a hybrid power unit of a self-propelled vehicle, the method employing:

- a first graph showing the power transmitted by the engine as a function of the rotation speed of a drive shaft, and for different injector openings of a power-regulating injection device; and
- a second graph showing the torque transmitted by the drive shaft as a function of the rotation speed of the drive shaft, and for different injector openings of the power-regulating injection device.

[0008] The method comprises the steps of:

(a) - dividing the y-axis of said first graph arbitrarily into a number of ranges advantageously, though not necessarily, of the same size;
(b) - inserting on the y-axis of said first graph the power value required to operate the self-propelled vehicle, so as to single out one of said ranges;
(c) - locating on said first graph the maximum power value in the range singled out at step (b);
(d) - determining on said first graph the drive shaft rotation speed corresponding to the maximum power value located at step (c);
(e) - transferring the rotation speed determined at step (d) to said second graph to locate the corresponding torque value;
(f) - locating on said second graph - at the point of intersection between the maximum-torque curve and the vertical line through the drive shaft rotation speed determined at step (d) - the partial-torque and relative injector opening curve through said point;
(g) - tracing the partial-torque curve on said second graph up to the intersection with the x-axis to determine the idling speed of the engine at the given injector opening; and
(h) - determining the position of the injection pump regulating member so as to inject fuel into the engine according to the injector opening determined at step (f).

[0009] A non-limiting embodiment of the present invention will now be described, by way of example, with reference to the accompanying drawings, in which:

Figure 1 shows a power unit of a self-propelled vehicle on which the method according to the present invention is implemented;
Figure 2 shows a graph employed in the method according to the invention and showing power transmission as a function of the rotational speed of the output shaft of an internal combustion engine forming part of the Figure 1 power unit; and
Figure 3 shows a graph employed in the method according to the invention in conjunction with the Figure 2 graph, and showing torque transmission as a function of the rotational speed of the output shaft of an internal combustion engine forming part of the Figure 1 power unit.

[0010] Number 1 in Figure 1 indicates as a whole a hybrid power unit for implementing the method accord-

ing to the present invention. Unit 1 in Figure 1 is a hybrid unit of which the components are arranged in series, but the teachings of the present invention may also be applied to advantage to any hybrid unit, in particular a parallel hybrid unit (not shown).

[0011] Unit 1 comprises an internal combustion engine 2, in particular a diesel engine, which, by means of a drive shaft 3, drives a generator 4 connected electrically to a charge device 5 for charging an electric energy storage device 6. Charge device 5 and storage device 6 are connected electrically to a device 7 for controlling an electric motor 8 powering an axle 9 of a vehicle (not shown). Fuel injection into internal combustion engine 2 is controlled by an injection device 10 comprising an injection pump 11, controlled by an actuating cylinder 12 via a lever mechanism 13, and an electronic board 14 for controlling the commands from an electronic central control unit 15.

[0012] The desired vehicle speed is entered by means of a pedal 16, or a hand lever 17 connected electrically in parallel with pedal 16. An electric line 18 connects pedal 16 and hand lever 17 to central control unit 15. As explained in detail later on, the operator, when selecting a given tilt angle α of pedal 16 or lever 17 (angle α in this case not shown) in actual fact merely selects the travelling speed of the vehicle. The electric signal generated by the operator at pedal 16 or lever 17 is transmitted to central control unit 15 for further processing to determine the state of device 10.

[0013] Figure 1 also shows how central control unit 15 controls device 10 using the method according to the present invention, which is described in detail below with reference to Figures 2 and 3.

[0014] Figure 2 shows a graph employed in the method according to the present invention, and which shows the variation in power P transmitted to output shaft 3 of engine 2 as a function of the rotational speed ωa of shaft 3. A number of curves are depicted showing the relation between power P and rotational speed ωa as a function of the injector opening of device 10, i.e. of injection pump 11.

[0015] It should be pointed out, in this context, that the term "injector opening" is intended to mean the injector opening directly proportional to the quantity of fuel injected into engine 2.

[0016] Figure 2 shows sixteen curves corresponding to injector openings ranging between 100% and 10%. More specifically, Figure 2 shows sixteen injector opening curves q ranging from a curve q0 showing the operation of engine 2 with a 100% injector opening, i.e. with pump 11 fully open to inject the maximum amount of fuel into engine 2, to a curve q1 showing operation of engine 2 with a 10% injector opening of pump 11.

[0017] Figure 2 also shows a curve q0' representing the envelope of the various opening curves q according to the maximum-opening curve q0.

[0018] Figure 3 shows a graph employed in the method according to the present invention together with the Figure 2 graph, and which shows the variation in torque C transmitted by engine 2 to drive shaft 3 as a function of the rotational speed ωa of shaft 3. Again, sixteen curves Q corresponding to injector openings ranging between 100% and 10% are depicted.

[0019] Also in Figure 3, curves Q include a maximum, i.e. 100%, opening curve Q0; a 10% opening curve Q1; and a curve Q0' representing the envelope of the various opening curves Q according to curve Q0.

[0020] As is known, the Figure 2 and 3 graphs are supplied by the manufacturer of engine 2 and normally vary from one engine to another. In other words, the Figure 2 and 3 graphs relate to a given engine 2 with given construction characteristics, which, in this purely illustrative context, need not be dealt with in detail.

[0021] As stated, for a clearer understanding of the method according to the present invention, reference will now be made to Figures 2 and 3.

[0022] The method according to the present invention employs:

- a first graph (Figure 2) showing the power P transmitted by engine 2 (Figure 1) as a function of the rotational speed ωa of drive shaft 3, and this for different injector openings of injection device 10 regulating power P; and
- a second graph (Figure 3) showing the torque C transmitted by drive shaft 3 as a function of the rotational speed ωa of drive shaft 3, and for different injector openings of power-regulating injection device 10.

[0023] The method comprises the steps of:

(a) - dividing the y-axis of the first graph (Figure 2) arbitrarily into a number of ranges of given, not necessarily equal, size (in the example shown, 10 ranges I1-I10 of equal size);

(b) - inserting on the y-axis of the first graph the power value P1 required to operate the self-propelled vehicle, so as to single out from ranges I1-I10 the one comprising power value P1 (range I8 in the example shown);

(c) - locating on the first graph (Figure 2) the maximum power value P2 in the range (I8) singled out at step (b);

(d) - determining on the first graph (Figure 2) - in particular, on curve q0' relative to maximum fuel injection into engine 2 - the rotational speed ωa of drive shaft 3 corresponding to the maximum power value P2 determined at step (c);

(e) - transferring the rotational speed ωa determined at step (d) to the second graph (Figure 3) to locate the corresponding torque value C1, which is located at the point of intersection P3 between the maximum-opening torque curve Q0' and the vertical line through ωa;

(f) - locating on the second graph (Figure 3) the par-

tial-torque and relative injector opening curve Q2 (in the example shown, the injector opening is 64%) through point P3 located at step (e) and corresponding to the rotational speed ωa and torque C1 determined at steps (d) and (e);

(g) - tracing on the second graph (Figure 3) the partial-torque curve Q2 corresponding to torque value C1 up to the intersection with the x-axis to determine the idling speed ω20 of the engine at the given injector opening; and

(h) - determining experimentally the position of actuator 12, regulating injection pump 11, which brings the idling speed of engine 2 to value ω20, so as to inject fuel into engine 2 according to the injector opening determined at step (f).

[0024] By determining idling speed ω0 for each injector opening curve Q, central control unit 15 can be calibrated accurately with no need for simulating engine 2 under load. Obviously, starting from the maximum idling speed on curve Q2, as load is applied to engine 2, rotational speed ωa decreases according to curve Q2 until the maximum torque value C1 is reached, thus achieving a minimum rotational speed ωa of shaft 3 and optimum operation of engine 2.

[0025] It should be pointed out that, even entering the maximum power value in a given range into the Figure 2 graph, does not necessarily mean that there will be a surplus amount of power for reuse, for example, by means of electric motor 8. In most cases, the surplus amount of power will not be supplied on account of (diesel) internal combustion engine 2 operating, at that particular speed, on a torque curve slightly lower than the maximum-torque curve.

[0026] In actual fact, the operator, using pedal 16 or hand lever 17, sets an ideal maximum power value, whereas the actual power supplied is a value between the ideal maximum and zero. In other words, if actuator cylinder 12 is set by the operator so that 64% of the fuel quantity is supplied by injection pump 11, internal combustion engine 2 can supply any power between zero and the set maximum value. Obviously, the closer P1 gets to the upper limit of range I8, the closer internal combustion engine 2 will operate to maximum torque, so that, once the Q curve (Figure 3) on which to operate is selected as described above, the speed of internal combustion engine 2 will tend towards rotational speed and torque values giving the required operating power P1 value.

[0027] In other words, the method according to the present invention may be said to substantially calibrate the opening of injection pump 12, so that, for a given power, the most favourable torque for the corresponding rotational speed of shaft 3 is achieved at all times to minimise consumption, noise level, etc.

Claims

1. A method of regulating and controlling an internal combustion engine (2) forming part of a hybrid power unit (1) of a self-propelled vehicle, the method employing:

    - a first graph showing the power (P) transmitted by the engine (2) as a function of the rotational speed (ωa) of a drive shaft (3), and for different injector openings of a power-regulating injection device (10); and
    - a second graph showing the torque (C) transmitted by the drive shaft (3) as a function of the rotational speed (ωa) of the drive shaft (3), and for different injector openings of the power-regulating injection device (10); and

    the method comprising the steps of:

    (a) - dividing the y-axis of the first graph arbitrarily into a number of ranges (I1-I10) not necessarily of the same size;

    (b) - inserting on the y-axis of said first graph the power value (P1) required to operate the self-propelled vehicle, so as to single out a particular range (I8) comprising said power value (P1);

    (c) - locating on the first graph the maximum power value (P2) in the range (I8) singled out at step (b) and located on a curve (q0') corresponding to the maximum injector opening of an injection pump (11) forming part of said power-regulating injection device (10);

    (d) - determining on the first graph the rotational speed (ωa) of the drive shaft (3) corresponding to the maximum power value (P2) determined at step (c);

    (e) - transferring the rotational speed (ωa) determined at step (d) to said second graph to locate the corresponding torque value (C1); said value being located at the point of intersection (P3) between the maximum injector opening torque curve (Q0') and a vertical line through said rotational speed (ωa);

    (f) - locating on the second graph the partial-torque and relative injector opening curve (Q2) through the point (P3) corresponding to the rotational speed (ωa) and torque value (C1) determined at steps (d) and (e);

    (g) - tracing on the second graph the partial-torque curve (Q2) corresponding to said torque value (C1) up to the intersection with the x-axis to determine the idling speed (ω20) of the engine at the given injector opening; and

    (h) - determining experimentally the position of an external actuator (12) for regulating said injection pump (11), so that said pump (11) is reg-

ulated to inject fuel into the engine (2) according to the injector opening determined at step (f).

2. A method according to claim 1, **characterized in that** said ranges (I1-I10) of step (a) are equal in size.

3. A method according to claim 1 or 2, **characterized in that** it is controlled by an electronic central control unit (15).

4. A hybrid power unit (1), **characterized in that** it comprises means for implementing the method according to claims 1 to 3.

5. A hybrid power unit (1) according to claim 4, **characterized in that** it comprises a diesel engine (2).

6. A hybrid power unit (1) according to claim 4 or 5, **characterized in that** the unit is a series type hybrid unit.

7. A hybrid power unit (1) according to claim 4 or 5, **characterized in that** the unit is a parallel type hybrid unit.

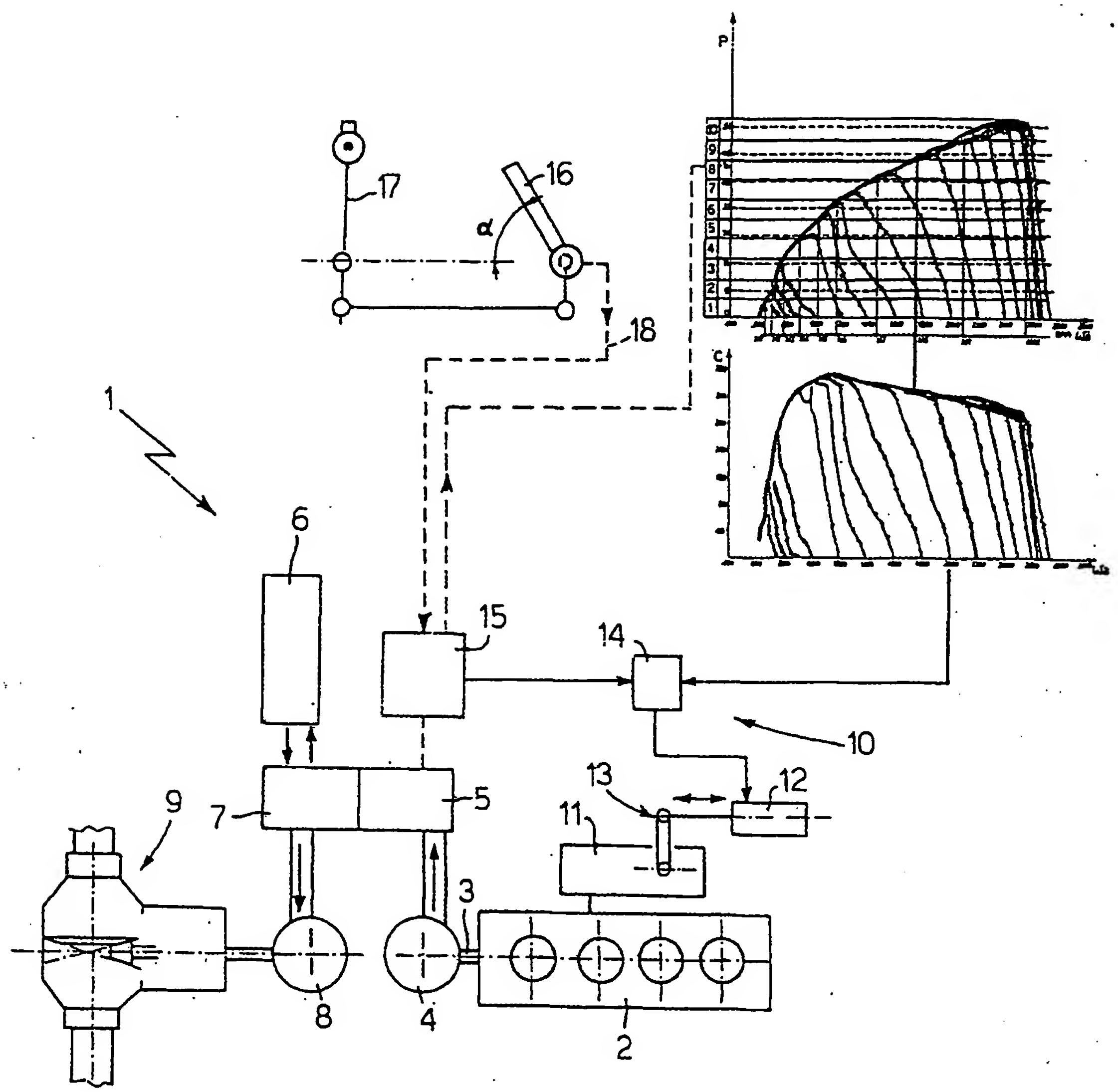
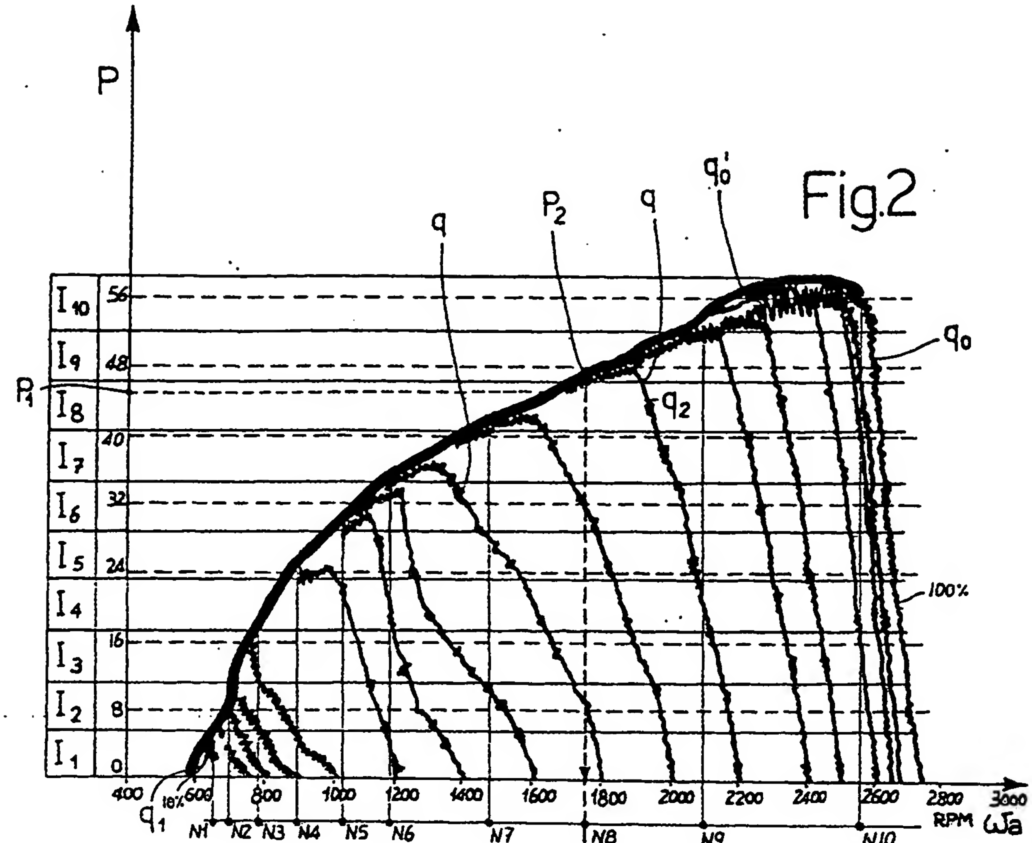


Fig.1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q
P2
q
q0'
I10
I9
I8
I7
I6
I5
I4
I3
I2
I1
56
48
40
32
24
16
8
0
P1
q2
q0
100%
q1
18%
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
2600
2800
3000
RPM
ωa
N1
N2
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N8
N9
N10

Fig.2

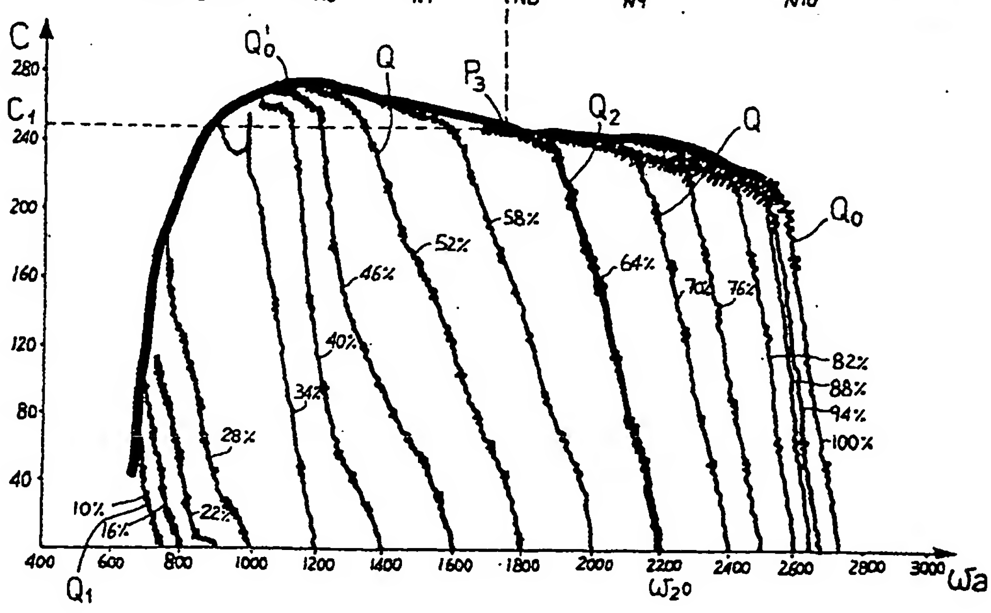
C
Q0'
Q
P3
Q2
Q
C1
280
240
200
160
120
80
40
58%
52%
46%
40%
34%
28%
22%
16%
10%
64%
70%
76%
82%
88%
94%
100%
Q0
Q1
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
2600
2800
3000
ωa
ω20

Fig.3

(19) Europäisches Patentamt
European Patent Office
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(11) EP 1 223 066 B1

(12) EUROPEAN PATENT SPECIFICATION

(45) Date of publication and mention of the grant of the patent: **26.04.2006 Bulletin 2006/17**

(51) Int Cl.:
B60K 6/04 (2006.01) *F02D 41/30* (2006.01)

(21) Application number: **01204265.1**

(22) Date of filing: **07.11.2001**

(54) Method of regulating and controlling an internal combustion engine

Verfahren zur Steuerung und Regelung einer Brennkraftmaschine

Procédé de régulation d'un moteur à combustion interne

(84) Designated Contracting States:
AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU MC NL PT SE TR

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(73) Proprietor: **CNH Italia S.p.A.**
41100 Modena (IT)

(72) Inventor: **Bordini, Giorgio,**
Edificio URBIS Portal 7 APT. 6B
E-38003 Santa Cruz de Tenerife,
Canarias (ES)

(74) Representative: **Vandenbroucke, Alberic**
CNH Belgium N.V.
Patent Department
Leon Claeysstraat, 3A
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EP 1 223 066 B1

Printed by Jouve, 75001 PARIS (FR)

Description

[0001] The present invention relates to a method of regulating and controlling an internal combustion engine forming part of a hybrid power unit of a self-propelled vehicle.

[0002] Known methods of controlling an internal combustion engine, in particular a diesel engine, are based on thousands of operational working points obtained from engine work graphs showing, for example, power and torque as a function of the rotational speed of the drive shaft. Since little ready-made data is normally available, composing reliable maps for a given engine is an enormous job in terms of data acquisition and, obviously, in terms of time and work, and seriously complicates the electronic central control unit regulating the actuator governing the diesel engine injection pump. A method with the features of the preamble of claim 1 is disclosed in EP 0556942 A.

[0003] It is therefore an object of the present invention to provide a simplified solution - albeit approximate but nevertheless acceptable - to the problem of regulating the injection of fuel in a diesel engine to ensure low consumption, low emission of harmful gases, a low noise level, and a long working life of the engine.

[0004] The method according to the present invention can only be applied to a hybrid power unit, which, as will be seen, allows to separate the control of the optimum engine conditions from the actual traction power required.

[0005] Since the engine-wheel gear ratio is continuously variable, vehicle speed may vary independently of engine speed, which may therefore be selected to suit a given vehicle speed, which at best should provide for reducing specific fuel consumption (SFC), pollutant emissions, noise level, and engine wear, while at the same time preserving the elasticity and control response of the engine.

[0006] For a given traction power, current regulating methods fail to provide for transmitting the power of the engine under maximum-torque conditions. Since specific fuel consumption of an engine is minimum under maximum torque conditions, and since the noise level also increases alongside engine speed, the engine, for a given traction power, should be operated at minimum speed while at the same time providing the mean traction power required by the terrain. For this to be done, the operating point of the engine must be located on the maximum-torque curve, which means that the right injection pump setting has to be determined at which the engine is enabled to supply the necessary instantaneous power in the best conditions referred to above.

[0007] According to the present invention, a method therefore is provided of calibrating the opening of an injection device of an internal combustion engine connected to a hybrid power unit of a self-propelled vehicle, the method employing:

- a first graph showing the power transmitted by the engine as a function of the rotation speed of a drive shaft, and for different injector openings of a power-regulating injection device; and
- a second graph showing the torque transmitted by the drive shaft as a function of the rotation speed of the drive shaft, and for different injector openings of the power-regulating injection device.

[0008] The method comprises the steps of:

(a) - dividing the y-axis of said first graph arbitrarily into a number of ranges advantageously, though not necessarily, of the same size;
(b) - inserting on the y-axis of said first graph the power value required to operate the self-propelled vehicle, so as to single out one of said ranges;
(c) - locating on said first graph the maximum power value in the range singled out at step (b);
(d) - determining on said first graph the drive shaft rotation speed corresponding to the maximum power value located at step (c);
(e) - transferring the rotation speed determined at step (d) to said second graph to locate the corresponding torque value;
(f) - locating on said second graph - at the point of intersection between the maximum-torque curve and the vertical line through the drive shaft rotation speed determined at step (d) - the partial-torque and relative injector opening curve through said point;
(g) - tracing the partial-torque curve on said second graph up to the intersection with the x-axis to determine the idling speed of the engine at the given injector opening; and
(h) - determining the position of the injection pump regulating member so as to inject fuel into the engine according to the injector opening determined at step (f).

[0009] A non-limiting embodiment of the present invention will now be described, by way of example, with reference to the accompanying drawings, in which:

Figure 1 shows a power unit of a self-propelled vehicle on which the method according to the present invention is implemented;
Figure 2 shows a graph employed in the method according to the invention and showing power transmission as a function of the rotational speed of the output shaft of an internal combustion engine forming part of the Figure 1 power unit; and
Figure 3 shows a graph employed in the method according to the invention in conjunction with the Figure 2 graph, and showing torque transmission as a function of the rotational speed of the output shaft of an internal combustion engine forming part of the Figure 1 power unit.

[0010] Number 1 in Figure 1 indicates as a whole a hybrid power unit for implementing the method according to the present invention. Unit 1 in Figure 1 is a hybrid unit of which the components are arranged in series, but the teachings of the present invention may also be applied to advantage to any hybrid unit, in particular a parallel hybrid unit (not shown).

[0011] Unit 1 comprises an internal combustion engine 2, in particular a diesel engine, which, by means of a drive shaft 3, drives a generator 4 connected electrically to a charge device 5 for charging an electric energy storage device 6. Charge device 5 and storage device 6 are connected electrically to a device 7 for controlling an electric motor 8 powering an axle 9 of a vehicle (not shown). Fuel injection into internal combustion engine 2 is controlled by an injection device 10 comprising an injection pump 11, controlled by an actuating cylinder 12 via a lever mechanism 13, and an electronic board 14 for controlling the commands from an electronic central control unit 15.

[0012] The desired vehicle speed is entered by means of a pedal 16, or a hand lever 17 connected electrically in parallel with pedal 16. An electric line 18 connects pedal 16 and hand lever 17 to central control unit 15. As explained in detail later on, the operator, when selecting a given tilt angle α of pedal 16 or lever 17 (angle α in this case not shown) in actual fact merely selects the travelling speed of the vehicle. The electric signal generated by the operator at pedal 16 or lever 17 is transmitted to central control unit 15 for further processing to determine the state of device 10.

[0013] Figure 1 also shows how central control unit 15 controls device 10 using the method according to the present invention, which is described in detail below with reference to Figures 2 and 3.

[0014] Figure 2 shows a graph employed in the method according to the present invention, and which shows the variation in power P transmitted to output shaft 3 of engine 2 as a function of the rotational speed ωa of shaft 3. A number of curves are depicted showing the relation between power P and rotational speed ωa as a function of the injector opening of device 10, i.e. of injection pump 11.

[0015] It should be pointed out, in this context, that the term "injector opening" is intended to mean the injector opening directly proportional to the quantity of fuel injected into engine 2.

[0016] Figure 2 shows sixteen curves corresponding to injector openings ranging between 100% and 10%. More specifically, Figure 2 shows sixteen injector opening curves q ranging from a curve q0 showing the operation of engine 2 with a 100% injector opening, i.e. with pump 11 fully open to inject the maximum amount of fuel into engine 2, to a curve q1 showing operation of engine 2 with a 10% injector opening of pump 11.

[0017] Figure 2 also shows a curve q0' representing the envelope of the various opening curves q according to the maximum-opening curve q0.

[0018] Figure 3 shows a graph employed in the method according to the present invention together with the Figure 2 graph, and which shows the variation in torque C transmitted by engine 2 to drive shaft 3 as a function of the rotational speed ωa of shaft 3. Again, sixteen curves Q corresponding to injector openings ranging between 100% and 10% are depicted.

[0019] Also in Figure 3, curves Q include a maximum, i.e. 100%, opening curve Q0; a 10% opening curve Q1; and a curve Q0' representing the envelope of the various opening curves Q according to curve Q0.

[0020] As is known, the Figure 2 and 3 graphs are supplied by the manufacturer of engine 2 and normally vary from one engine to another. In other words, the Figure 2 and 3 graphs relate to a given engine 2 with given construction characteristics, which, in this purely illustrative context, need not be dealt with in detail.

[0021] As stated, for a clearer understanding of the method according to the present invention, reference will now be made to Figures 2 and 3.

[0022] The method according to the present invention employs:

- a first graph (Figure 2) showing the power P transmitted by engine 2 (Figure 1) as a function of the rotational speed ωa of drive shaft 3, and this for different injector openings of injection device 10 regulating power P; and
- a second graph (Figure 3) showing the torque C transmitted by drive shaft 3 as a function of the rotational speed ωa of drive shaft 3, and for different injector openings of power-regulating injection device 10.

[0023] The method comprises the steps of:

(a) - dividing the y-axis of the first graph (Figure 2) arbitrarily into a number of ranges of given, not necessarily equal, size (in the example shown, 10 ranges I1-I10 of equal size);

(b) - inserting on the y-axis of the first graph the power value P1 required to operate the self-propelled vehicle, so as to single out from ranges I1-I10 the one comprising power value P1 (range I8 in the example shown);

(c) - locating on the first graph (Figure 2) the maximum power value P2 in the range (I8) singled out at step (b);

(d) - determining on the first graph (Figure 2) - in particular, on curve q0' relative to maximum fuel injection into engine 2 - the rotational speed ωa of drive shaft 3 corresponding to the maximum power value P2 determined at step (c);

(e) - transferring the rotational speed ωa determined at step (d) to the second graph (Figure 3) to locate the corresponding torque value C1 which is located at the point of intersection P3 between the maximum-opening torque curve Q0' and the vertical line

through ωa;

(f) - locating on the second graph (Figure 3) the partial-torque and relative injector opening curve Q2 (in the example shown, the injector opening is 64%) through point P3 located at step (e) and corresponding to the rotational speed ωa and torque C1 determined at steps (d) and (e);

(g) - tracing on the second graph (Figure 3) the partial-torque curve Q2 corresponding to torque value C1 up to the intersection with the x-axis to determine the idling speed ω20 of the engine at the given injector opening; and

(h) - determining experimentally the position of actuator 12, regulating injection pump 11, which brings the idling speed of engine 2 to value ω20, so as to inject fuel into engine 2 according to the injector opening determined at step (f).

[0024] By determining idling speed ω0 for each injector opening curve Q, central control unit 15 can be calibrated accurately with no need for simulating engine 2 under load. Obviously, starting from the maximum idling speed on curve Q2, as load is applied to engine 2, rotational speed ωa decreases according to curve Q2 until the maximum torque value C1 is reached, thus achieving a minimum rotational speed ωa of shaft 3 and optimum operation of engine 2.

[0025] It should be pointed out that, even entering the maximum power value in a given range into the Figure 2 graph, does not necessarily mean that there will be a surplus amount of power for reuse, for example, by means of electric motor 8. In most cases, the surplus amount of power will not be supplied, on account of (diesel) internal combustion engine 2 operating, at that particular speed, on a torque curve slightly lower than the maximum-torque curve.

[0026] In actual fact, the operator, using pedal 16 or hand lever 17, sets an ideal maximum power value, whereas the actual power supplied is a value between the ideal maximum and zero. In other words, if actuator cylinder 12 is set by the operator so that 64% of the fuel quantity is supplied by injection pump 11, internal combustion engine 2 can supply any power between zero and the set maximum value. Obviously, the closer P1 gets to the upper limit of range I8, the closer internal combustion engine 2 will operate to maximum torque, so that, once the Q curve (Figure 3) on which to operate is selected as described above, the speed of internal combustion engine 2 will tend towards rotational speed and torque values giving the required operating power P1 value.

[0027] In other words, the method according to the present invention may be said to substantially calibrate the opening of injection pump 12, so that, for a given power, the most favourable torque for the corresponding rotational speed of shaft 3 is achieved at all times to minimise consumption, noise level, etc.

Claims

1. A method of calibrating the opening of an injection device (10) of an internal combustion engine (2) forming part of a hybrid power unit (1) of a self-propelled vehicle, the method employing:

   - a first graph showing the power (P) transmitted by the engine (2) as a function of the rotational speed (ωa) of a drive shaft (3), and for different injector openings of a power-regulating injection device (10); and
   - a second graph showing the torque (C) transmitted by the drive shaft (3) as a function of the rotational speed (ωa) of the drive shaft (3), and for different injector openings of the power-regulating injection device (10); and

   the method comprising the steps of:

   (a) - dividing the y-axis of the first graph arbitrarily into a number of ranges (I1-I10) not necessarily of the same size;

   (b) - inserting on the y-axis of said first graph the power value (P1) required to operate the self-propelled vehicle, so as to single out a particular range (I8) comprising said power value (P1);

   the method being chararacterised by the following steps:

   (c) - locating on the first graph the maximum power value (P2) in the range (I8) singled out at step (b) and located on a curve (q0') corresponding to the maximum injector opening of an injection pump (11) forming part of said power-regulating injection device (10);

   (d) - determining on the first graph the rotational speed (ωa) of the drive shaft (3) corresponding to the maximum power value (P2) determined at step (c);

   (e) - transferring the rotational speed (ωa) determined at step (d) to said second graph to locate the corresponding torque value (C1); said value being located at the point of intersection (P3) between the maximum injector opening torque curve (Q0') and a vertical line through said rotational speed (ωa);

   (f) - locating on the second graph the partial-torque and relative injector opening curve (Q2) through the point (P3) corresponding to the rotational speed (ωa) and torque value (C1) determined at steps (d) and (e);

   (g) - tracing on the second graph the partial-torque curve (Q2) corresponding to said torque value (C1) up to the intersection with the x-axis to determine the idling speed (ω20) of the engine at the given injector

opening; and

(h) - determining experimentally the position of an external actuator (12) for regulating said injection pump (11), so that said pump (11) is regulated to inject fuel into the engine (2) according to the injector opening determined at step (f).

2. A method according to claim 1, **characterized in that** said ranges (I1-I10) of step (a) are equal in size.

3. A method according to claim 1 or 2, **characterized in that** said vehicle comprises an electronic central control unit (15) operably connected to said internal combustion engine for operating said method.

4. A hybrid power unit (1), **characterized in that** it comprises means for implementing the method according to claims 1 to 3.

5. A hybrid power unit (1) according to claim 4, **characterized in that** it comprises a diesel engine (2).

6. A hybrid power unit (1) according to claim 4 or 5, **characterized in that** the unit is a series type hybrid unit.

7. A hybrid power unit (1) according to claim 4 or 5, **characterized in that** the unit is a parallel type hybrid unit.

Revendications

1. Méthode pour calibrer l'ouverture d'un dispositif d'injection (10) d'un moteur à combustion interne (2) relié à une unité de puissance hybride d'un véhicule automoteur (1), ladite méthode utilisant :

- un premier graphique illustrant la puissance (P) transmise par le moteur (2)) en fonction de la vitesse de rotation (ωa) de l'arbre de commande (3) et ceci, pour différentes ouvertures d'injecteur du dispositif d'injection (10) régulant la puissance ; et
- un deuxième graphique illustrant le couple (C) transmis par l'arbre de commande (3) en fonction de la vitesse de rotation (ωa) de l'arbre de commande (3), ainsi que pour différentes ouvertures d'injecteur de régulation de puissance du dispositif d'injection (10); et

la méthode comprenant les étapes suivantes :

(a) - division de l'axe y du premier graphique arbitrairement en un certain nombre de secteurs de dimension donnée mais non nécessairement égale (I1-I10) ;

(b) - insertion sur l'axe y du premier graphique de la valeur de puissance (P1) exigée pour faire fonctionner le véhicule automoteur, de manière à individualiser un secteur particulier (18) comprenant ladite valeur de puissance (P1) ; la méthode étant **caractérisée par** les étapes suivantes :

(c) - établissement sur le premier graphique de la valeur de puissance maximum (P2) dans le secteur (18) individualisé lors de l'étape (b) et situé sur une courbe (q0') correspondant à l'ouverture d'injecteur maximum d'une pompe d'injection (11) faisant partie dudit dispositif d'injection de régulation de la puissance (10) ;

(d) - détermination sur le premier graphique la vitesse de rotation (ωa) de l'arbre de commande (3) correspondant à la valeur de la puissance maximum (P2) déterminée lors de l'étape (c) ;

(e) - transfert de la vitesse de rotation (ωa) déterminée lors de l'étape (d) vers le deuxième graphique de manière à établir la valeur du couple correspondant (C1); cette valeur étant établie au point d'intersection (P3) entre la courbe du couple d'ouverture maximum (Q0') et la verticale passant par ladite vitesse de rotation (ωa) ;

(f) - établissement sur le deuxième graphique du couple partiel et de la courbe d'ouverture d'injecteur relative (Q2) passant par le point (P3) correspondant à la vitesse de rotation (ωa) et au couple (C1) déterminé lors des étapes (d) et (e) ;

(g) - tracé sur le deuxième graphique de la courbe du couple partiel (Q2) correspondant à la valeur du couple (C1) jusqu'à l'intersection avec l'axe x de manière à définir la vitesse de ralenti (ω20) du moteur pour l'ouverture d'injecteur donnée; et

(h) - détermination, par voie expérimentale, de la position de l'actionneur (12) régulant la pompe d'injection (11), (11) de manière à réguler ladite pompe (11) pour injecter le carburant dans le moteur (2) selon l'ouverture d'injecteur déterminée lors de l'étape (f).

2. Méthode selon la revendication 1, **caractérisée en ce que** lesdits secteurs (I1-I10) de l'étape (a) ont des dimensions égales.

3. Méthode selon la revendication 1 ou 2, **caractérisée en ce que** ledit véhicule comprend une unité électronique de commande centrale (15) reliée de manière fonctionnelle audit moteur à combustion interne pour exécuter ladite méthode.

4. Unité de puissance hybride (1), **caractérisée en ce**

qu'elle comprend des moyens pour mettre en oeuvre la méthode selon les revendications 1 à 3.

5. Unité de puissance hybride (1) selon la revendication 4, **caractérisée en ce qu'**elle comprend un moteur diesel (2).

6. Unité de puissance hybride (1) selon la revendication 4 ou 5, **caractérisée en ce que** l'unité est une unité hybride du type en série.

7. Unité de puissance hybride (1) selon la revendication 4 ou 5, **caractérisée en ce que** l'unité est une unité hybride du type en parallèle.

Patentansprüche

1. Verfahren zum Kalibrieren der Öffnung einer Einspritzeinrichtung (10) eines Verbrennungsmotors (2), der Teil einer Hybrid-Leistungseinheit (1) eines selbstfahrenden Fahrzeuges bildet, wobei das Verfahren folgendes verwendet:

   - ein erstes Diagramm, das die von dem Motor (2) übertragene Leistung (P) als eine Funktion der Drehgeschwindigkeit (ωa) einer Antriebswelle (3) und für unterschiedliche Einspritzdüsen-Öffnungen einer die Leistung regelnden Einspritzeinrichtung (10) zeigt; und
   - ein zweites Diagramm, dass das von der Antriebswelle (3) übertragene Drehmoment (C) als eine Funktion der Drehgeschwindigkeit (ωa) der Antriebswelle (3) und für unterschiedliche Einspritzdüsen-Öffnungen der die Leistung regelnden Einspritzeinrichtung (10) zeigt; und

   wobei das Verfahren die folgenden Schritte umfasst:

   (a) - Unterteilen der y-Achse des ersten Diagramms willkürlich in eine Anzahl von Bereichen (I1 - I10), die nicht notwendigerweise die gleiche Größe aufweisen;
   (b) - Einsetzen, auf der y-Achse des ersten Diagramms, des Leistungswertes (P1), der zum Betrieb des selbstfahrenden Fahrzeuges erforderlich ist, um einen bestimmten Bereich (18) auszuwählen, der den Leistungswert (P1) umfasst; wobei das Verfahren durch die folgenden Schritte **gekennzeichnet** ist:
   (c) - Lokalisieren, auf dem ersten Diagramm, des maximalen Leistungswertes (P2) in dem Bereich (18), der im Schritt (b) ausgewählt wurde und auf einer Kurve (q0') liegt, die der maximalen Einspritzdüsen-Öffnung einer Einspritzpumpe (11) entspricht, die einen Teil der leistungsregelnden Einspritzeinrichtung (10) bildet;
   (d) - Bestimmen, auf dem ersten Diagramm, der Drehgeschwindigkeit (ωa) der Antriebswelle (3), die dem maximalen Leistungswert (P2) entspricht, der im Schritt (c) bestimmt wurde;
   (e) - Übertragen der Drehgeschwindigkeit (ωa), die im Schritt (d) bestimmt wurde, auf das zweite Diagramm zum Lokalisieren des entsprechenden Drehmomentwertes, wobei der Wert auf dem Schnittpunkt (P3) zwischen der Drehmoment-Kurve (Q0') für die maximale Einspritzdüsen-Öffnung und einer vertikalen Linie durch die Drehgeschwindigkeit (ωa) liegt;
   (f) - Lokalisieren, auf dem zweiten Diagramm, des Teil-Drehmomentes und der relativen Einspritzdüsen-Öffnungskurve (Q2) durch den Punkt (P3), der der Drehgeschwindigkeit (ωa) und dem Drehmoment-Wert (C1) entspricht, die in den Schritten (d) und (e) bestimmt wurden;
   (g) - Verfolgen, auf dem zweiten Diagramm, der Teil-Drehmoment-Kurve (Q2), die dem Drehmoment-Wert (C1) entspricht, bis zu dem Schnittpunkt mit der x-Achse zur Bestimmung der Leerlaufdrehzahl ($\omega 20$) des Motors bei der vorgegebenen Einspritzdüsen-Öffnung; und
   (h) - experimentelles Bestimmen der Position eines externen Stellgliedes (12) zum Regeln der Einspritzpumpe (11) derart, dass die Pumpe (11) so geregelt wird, dass sie Treibstoff in den Motor (2) entsprechend der Einspritzdüsen-Öffnung einspritzt, die im Schritt (f) bestimmt wurde.

2. Verfahren nach Anspruch 1, **dadurch gekennzeichnet, dass** die Bereiche (I1-I10) des Schrittes (a) eine gleiche Größe aufweisen.

3. Verfahren nach Anspruch 1 oder 2, **dadurch gekennzeichnet, dass** das Fahrzeug eine elektronische zentrale Steuereinheit (15) umfasst, die betriebsmäßig mit dem Verbrennungsmotor verbunden ist, um das Verfahren zu betreiben.

4. Hybrid-Leistungseinheit (1), **dadurch gekennzeichnet, dass** sie Einrichtungen zur gerätemäßigen Ausgestaltung des Verfahrens nach den Ansprüchen 1 bis 3 umfasst.

5. Hybrid-Leistungseinheit (1) nach Anspruch 4, **dadurch gekennzeichnet, dass** sie einen Dieselmotor (2) umfasst.

6. Hybrid-Leistungseinheit (1) nach Anspruch 4 oder 5, **dadurch gekennzeichnet, dass** die Einheit eine Hybrid-Einheit vom Serientyp ist.

7. Hybrid-Leistungseinheit (1) nach Anspruch 4 oder 5, **dadurch gekennzeichnet, dass** die Einheit eine Hybrid-Einheit vom parallelen Typ ist.

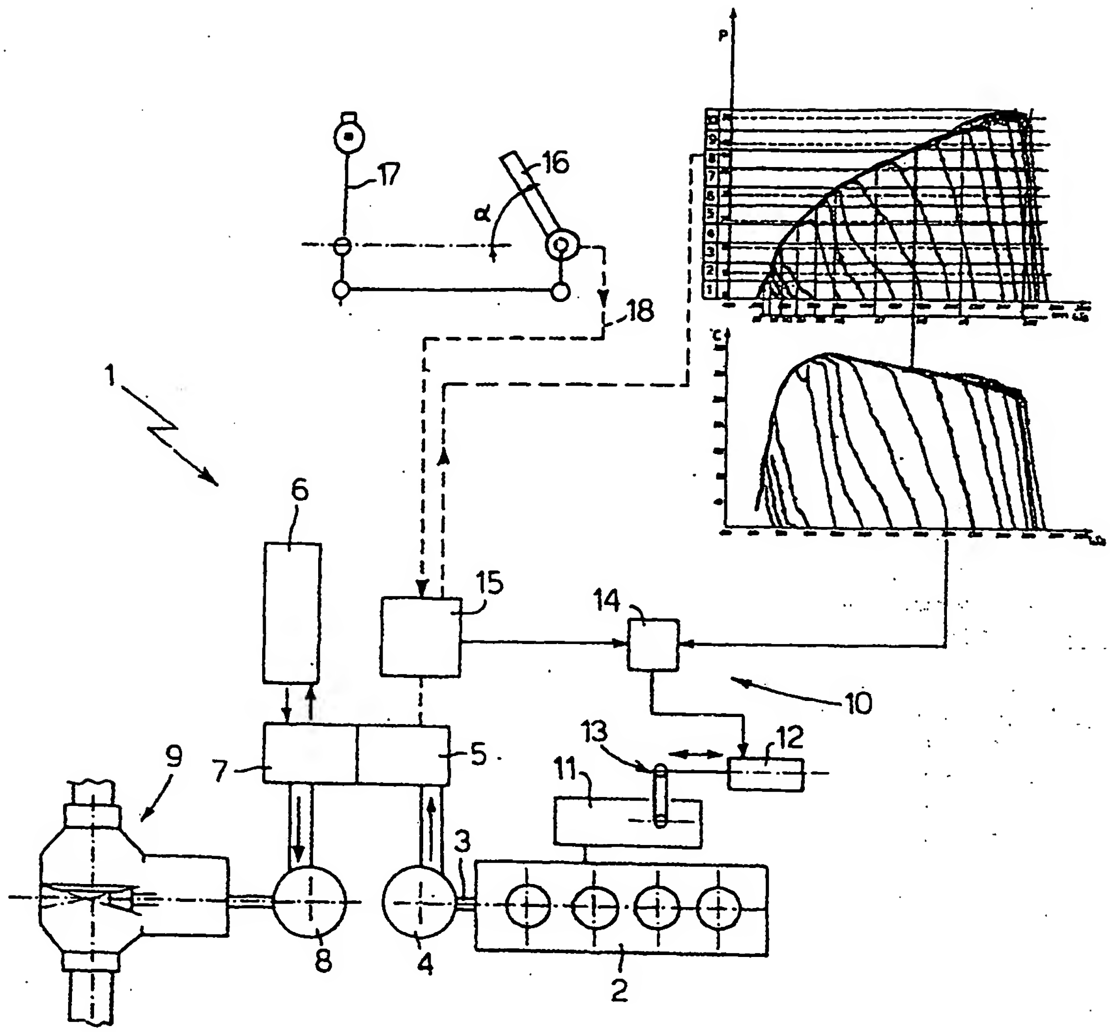


Fig.1

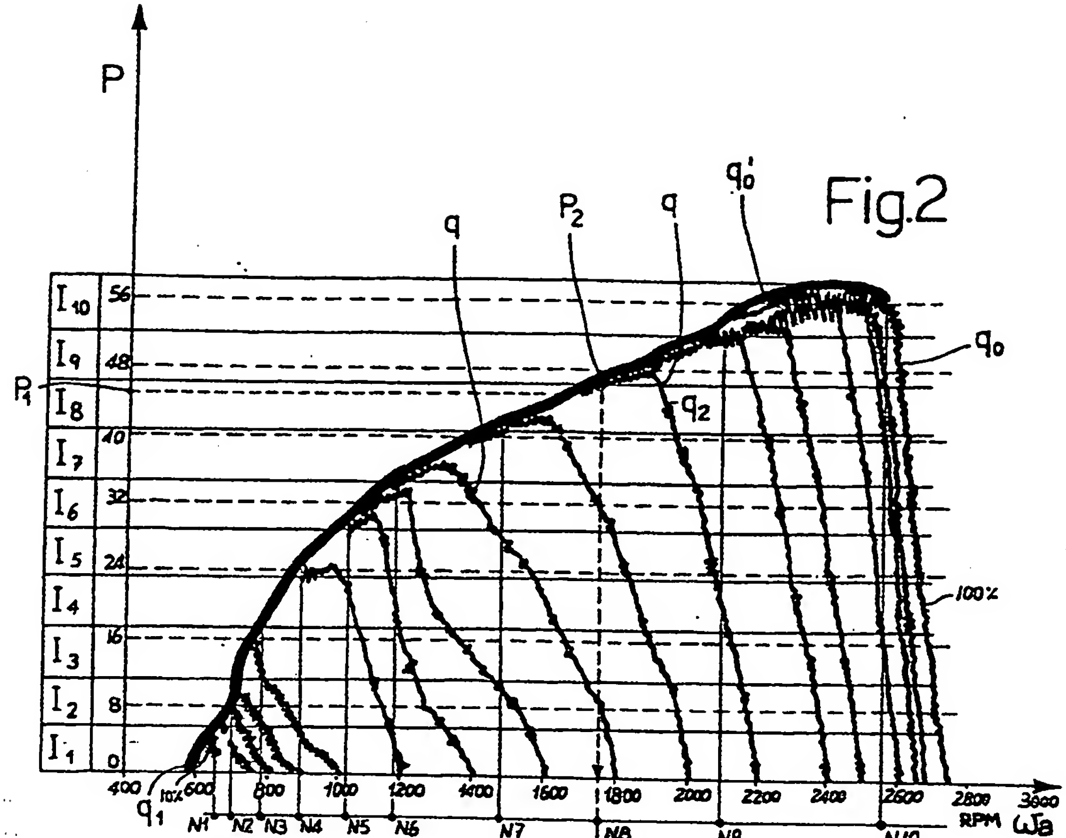
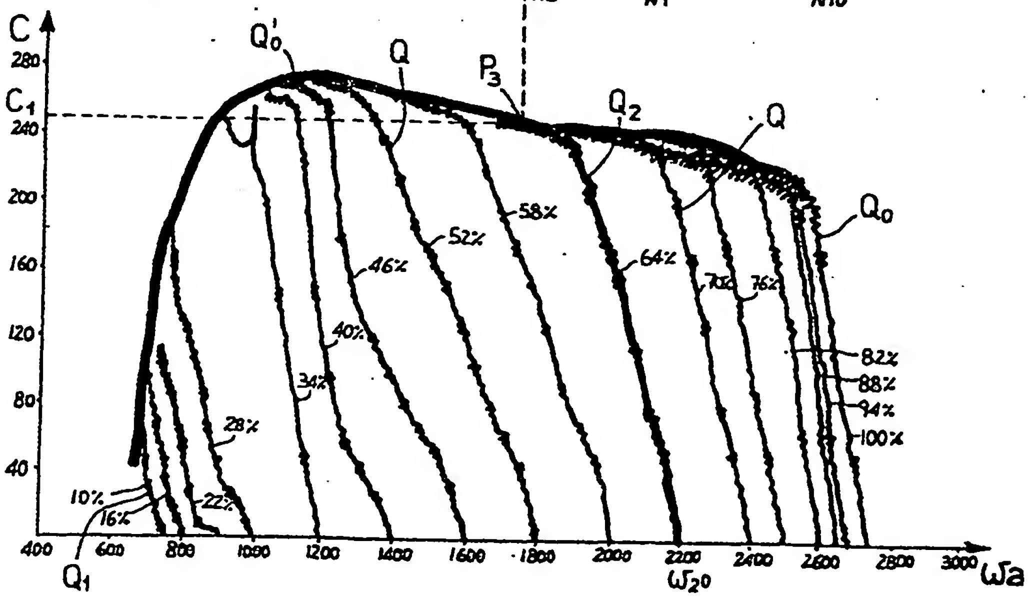

P
q
P2
q
q0'
q0
q2
P1
I1
I2
I3
I4
I5
I6
I7
I8
I9
I10
0
8
16
24
32
40
48
56
100%
10%
q1
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
2600
2800
3000
N1
N2
N3
N4
N5
N6
N7
N8
N9
N10
RPM
ωa

Fig.2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C1
280
240
200
160
120
80
40
Q0'
Q
P3
Q2
Q
Q0
58%
52%
46%
64%
70%
76%
40%
34%
28%
22%
10%
16%
82%
88%
94%
100%
Q1
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
2600
2800
3000
ω20
ωa

Fig.3